TYPE Original Research
PUBLISHED 09 October 2024
DOI 10.3389/feduc.2024.1392266

OPEN ACCESS

EDITED BY
Heidi Kloos,
University of Cincinnati, United States

REVIEWED BY
Muhammad Kristiawan,
University of Bengkulu, Indonesia
Erikson Saragih,
University of North Sumatra, Indonesia
M. Habibi,
Universitas Negeri Padang, Indonesia

*CORRESPONDENCE
Shaymaa E. Sorour
✉ ssorour@kfu.edu.sa

RECEIVED 05 April 2024
ACCEPTED 24 September 2024
PUBLISHED 09 October 2024

CITATION
Sorour SE, Ahmed RJM and Abd El Aziz MI (2024) A multi-smart agent-based training environment for enhancing 3D graphics production and design thinking skills among elementary computer teachers.
Front. Educ. 9:1392266.
doi: 10.3389/feduc.2024.1392266

A multi-smart agent-based training environment for enhancing 3D graphics production and design thinking skills among elementary computer teachers

Shaymaa E. Sorour[1,2]*, Rahma J. M. Ahmed[3] and Mahmoud I. Abd El Aziz[3]

[1]Department of Management Information Systems, College of Business Administration, King Faisal University, Al Ahsa, Saudi Arabia, [2]Faculty of Specific Education, Kafrelsheikh University, Kafr El-Shaikh, Egypt, [3]Faculty of Education, Kafrelsheikh University, Kafr El-Shaikh, Egypt

This study introduces a multi-smart agent-based training environment aimed at enhancing the production of 3D graphics and fostering design-thinking skills among primary-stage computer teachers. This environment offers a collaborative and interactive learning experience using intelligent agents represented as animated characters. The research evaluates the effectiveness of this innovative training approach through experimental groups, demonstrating significant improvements in the cognitive and psychomotor domains of 3D graphics production skills and in developing design thinking. The results underscore the potential of smart agent technology in educational settings, offering a dynamic platform for teacher professional development by integrating modern technological tools and creative problem-solving methodologies. This study pioneers using multi-smart agent environments in primary education, providing a novel framework that significantly enhances educators' skills and prepares them for future technological advancements in teaching.

KEYWORDS

3D graphics production, design thinking smart agent technology, teacher professional development, virtual training environments, smart agent technology

1 Introduction

Enhancing teacher competencies, skills, and training is essential for improving educational outcomes globally. Teachers play a crucial role in nurturing innovative capabilities in students, which are fundamental to national competitiveness and progress (Abah, 2021; Bates, 2021; Gikandi and Davis, 2019). As a result, numerous educational paradigms have been developed to refine teachers' competencies, particularly for computer educators requiring diverse skills to fulfill their roles in modern educational settings. These skills encompass a broad range of personal attributes, cognitive abilities, social skills, and ethical considerations (Gikandi and Davis, 2019).

In developed nations, there is significant emphasis on equipping educators with foundational skills through structured teacher preparation and in-service training programs (Robert, 2015). These initiatives aim to enhance teachers' abilities to adapt to advancements in various scientific and technological domains. Given their direct interaction with students, teachers are critical facilitators in developing students' abilities and skills, highlighting the importance of continuous professional development (Crompton and Burke, 2020; Saleh and Saadeh, 2022).

Despite recognizing these needs, a considerable gap remains in effectively integrating educational technologies into teacher training programs. Traditional training methods often fail to provide educators with the practical skills needed to incorporate advanced technologies, particularly in computer education (Crompton and Burke, 2020). This gap is especially evident in primary education, where teachers require ongoing training to keep pace with rapid technological advancements (Gilbert and Levine, 2021).

Recent advancements in educational technology offer promising solutions to these challenges. Virtual training environments and intelligent agents have emerged as innovative tools that can transform teacher education by providing interactive and personalized learning experiences (Weber et al., 2017; Njenga et al., 2017; Kim and Bonk, 2021; Ertmer and Ottenbreit-Leftwich, 2023). These technologies enable educators to engage more deeply with content, fostering cognitive and practical skill development in a dynamic and supportive learning environment (Ahmed, 2023).

1.1 Research problem

This study addresses a critical problem in the current educational landscape: the inadequacy of existing training methodologies in effectively equipping primary-stage computer teachers with essential skills in 3D graphics production and design thinking. Current training programs often fail to leverage advanced technologies, such as intelligent agent environments, which offer interactive and personalized learning experiences that could bridge this gap.

1.2 Objectives

The main objectives of this study are:

- To design and implement a training environment based on a multi-smart agent model that enhances 3D graphics production skills among elementary computer teachers.
- To foster design thinking skills in teachers through advanced virtual training tools.
- To evaluate the effectiveness of the multi-smart agent training environment in improving computer teachers' cognitive and performance skills.

1.3 Research questions

This study seeks to answer the following research questions:

- **Q1:** What specific skills in 3D graphics production are necessary for computer teachers in the primary stage?
- **Q2:** What are the criteria for designing a training environment based on the multi-smart agent model?
- **Q3:** How does the educational design used in this training environment facilitate learning?
- **Q4:** What is the effectiveness of the multi-smart agent training environment in developing cognitive skills related to 3D graphics among teachers?
- **Q5:** How effective is the training environment in enhancing the psychomotor domain of 3D graphics skills?
- **Q6:** Does the multi-smart agent training environment improve the quality of the final product in 3D graphics production?
- **Q7:** How does the training environment impact design thinking skills among computer teachers in the primary stage?

1.4 Contributions

This study makes several significant contributions to the fields of educational technology and teacher training:

- **Development of a multi-smart agent training environment:** the research introduces an innovative training environment explicitly designed for primary-stage computer teachers, integrating multiple intelligent agents to enhance technical and creative learning experiences.
- **Enhancement of 3D graphics production skills:** the study outlines a framework for improving 3D graphics production skills among teachers, which is increasingly essential as modern educational contexts rely more on digital content creation.
- **Promotion of design thinking:** by incorporating design thinking into the training process, the study fosters creativity and adaptability among teachers, encouraging them to adopt innovative problem-solving approaches in their teaching methods.
- **Empirical evaluation of training effectiveness:** the research comprehensively evaluates the training environment's effectiveness, offering valuable insights into how intelligent agent technology can improve educators' cognitive and performance skills.
- **Framework for technological integration in teacher training:** the study presents a practical framework for integrating advanced technologies into teacher training programs, setting a new benchmark for professional development in education.
- **Contribution to knowledge on intelligent agents:** the research advances our understanding of how intelligent agents can be utilized effectively in educational settings, contributing to the broader discourse on technology-enhanced learning.
- **Addressing the gap in primary education:** the study explicitly targets the gap in primary education, offering solutions that address computer teachers' unique challenges at this educational level.
- **Guidance for future research:** the findings and methodologies presented in this study provide a solid foundation for future research, guiding further exploration

into the use of intelligent agents in educational environments and beyond.

1.5 Structure

This document is organized as follows: Section 2 provides a thorough review of relevant literature. Section 3 details the proposed model and its components. Sections 4 and 5 present the methods and the experimental results in a structured manner. Finally, Sections 6 and 7 summarize the essential findings and suggest directions for future research.

2 Literature review

The enhancement of teachers' competencies, skills, and training is recognized as crucial in education systems worldwide, transcending the developmental status of countries. Teachers are pivotal in nurturing students' innovative capabilities, essential for national competitiveness (Abah, 2021). As a result, numerous educational paradigms have emerged, focusing on refining teachers' competencies to enable them to fulfill their responsibilities effectively. For computer educators, this involves diverse skills, including personal attributes, cognitive capabilities, psychological and social skills, and moral dimensions (Robert, 2015).

In developed countries, equipping educators with essential skills has become a distinguishing feature of teacher preparation and in-service training programs. These initiatives aim to enhance teachers' capacities, allowing them to adapt to scientific advancements and foster the development of student's abilities (Al-Mozan, 2015; Qteit, 2015). Technological innovations play a significant role in this process, necessitating a proactive approach to preparing and training educators in the proficient design, production, and utilization of these advancements (Qteit, 2011).

Virtual training environments have emerged as a viable solution to the challenges associated with professional development. By leveraging virtual training, educators can enhance ongoing skills and improve productivity, organizational efficacy, and skill deficits (Abdul Rahman, 2019). Virtual training environments integrate various elements and classifications, such as training and e-learning systems, virtual reality environments, and cloud computing environments, to create a multifaceted approach to advancing educational methodologies (Khamis, 2015; Al-Qarni, 2018).

The design of virtual training environments should prioritize diversity and richness in methodologies and activities, facilitating trainee participation and interaction. A well-designed virtual environment guides trainees in organizing electronic information sources effectively, catering to varied learning styles and fostering effective engagement (Abu Al-Dahab, 2020). Virtual environments also emphasize cognitive and constructivist learning, promoting social learning through synchronous and asynchronous communication channels (Qteit, 2015; Al-Mozan, 2015).

Recent research has gained significant attention on integrating intelligent agents into virtual training environments. Intelligent agents enhance trainee integration, boost interactivity, and add dynamism to the training process (Bassiouni, 2005; Weber et al., 2017). They serve as vital elements in teaching, learning, and training, offering a platform for presenting, organizing, and selecting learning materials based on trainees' characteristics. Intelligent agents also provide timely reinforcement and address inquiries, enhancing performance and achieving training goals (Assiri, 2017; Ahmed, 2019).

Intelligent agents exhibit various characteristics, including adaptation, asynchrony, flexibility, goal orientation, and cooperation (Nazir, 2017). They function as personal assistants, supporting trainees in completing tasks and facilitating interactions with various inputs and outputs. Intelligent agents can operate independently or under trainee control, simulating verbal and non-verbal communication and acknowledging trainees' needs based on adaptive knowledge bases (Assiri, 2017; Brazier and Ogston, 2011).

Research has highlighted the effectiveness of multi-directed intelligent agents in virtual training environments. These agents, represented as animated characters, function as collaborative guides, dividing training topics into tasks and assisting trainees in problem-solving (Kiourt et al., 2017). The multi-directed intelligent agent style enhances motivation by serving as visual stimuli and offering interactive scenarios that simulate problem-solving challenges (Liu et al., 2017).

Furthermore, the 3D graphics approach in electronic content design has become a modern technology for teaching academic courses. Three-dimensional graphics enhance engagement and comprehension by providing a mathematical representation of objects that can be modified and rotated (Glick et al., 2012; Scott Glick et al., 2012). This approach efficiently transitions from abstract concepts to tangible experiences, contributing to improved student performance and motivation (Salem, 2018; Khalil, 2018).

The open-source SketchUp program will be employed in this research to produce three-dimensional drawings. This tool allows teachers to generate educational elements with realistic characteristics, enhancing immersion in the learning process. Design thinking, closely aligned with how designers think and work, offers a framework for experimenting with idea generation and fostering creativity (Mootee, 2011).

Design thinking emphasizes creative problem-solving methods and systems thinking, integral to understanding and addressing educational challenges (Iyad, 2015). The current research builds upon these insights to enhance 3D graphics production skills and instill design thinking among computer teachers through a multi-smart agent-based training environment.

3 Proposed model

This section outlines the proposed model, which is designed to enhance 3D graphics production and foster design thinking among elementary school computer teachers. The model features animated, AI-powered characters. These intelligent agents simulate real-life tasks, provide step-by-step instructions, deliver immediate feedback, and assist in solving complex problems, thus offering a dynamic, interactive learning experience tailored to improve cognitive and practical skills.

The proposed model is built on a systematic approach integrating educational technology and interactive training environments. It leverages multi-smart agent technology to create a dynamic and engaging learning experience structured through the following key stages:

1. **Preparation of interactive video design skills:**
    - Establish a preliminary list of essential 3D graphics production skills tailored for primary-stage computer teachers.
    - Refine the skills list through expert evaluation, resulting in a comprehensive set of 6 main stages, 28 primary skills, and 12 sub-skills, encompassing 189 performance indicators.
2. **Development of training environment design standards:**
    - Create a detailed list of standards for designing the training environment, expressed in clear and measurable terms.
    - Adjust the list based on input from educational technology specialists, finalizing it with four main areas, 23 sub-criteria, and 274 sub-indicators.
3. **Educational design process:**
    a. **Introductory evaluation:**
        - Assess teachers' proficiency in internet usage, electronic device handling, and familiarity with web applications.
        - Ensure resource availability and obtain necessary approvals for the research experiment.
        - Conduct a cost-benefit analysis to outline the anticipated benefits of enhancing 3D graphics production skills and design thinking.

    b. **Preparation stage:**
        - Identify and address shortcomings based on teachers' experiences with the technology and the training environment.
        - Establish the technological infrastructure and determine the work team.

    c. **Analysis stage:**
        - Define general objectives for the training content and identify training needs.
        - Analyze resources and constraints and define responsibilities and tasks.

    d. **Design stage:**
        - Formulate procedural objectives and design training content.
        - Develop multimedia resources, interaction interfaces, and assessment tools.
        - Design scenarios and event boards to guide the training process.

    e. **Production stage:**
        - Produce multimedia content, training activities, and internal interactions.
        - Create a guide for using the training environment.

    f. **Evaluation stage:**
        - Test the training environment and monitor results.
        - Implement final modifications based on feedback.

    g. **Application stage:**
        - Deploy the training environment in real-world settings.
        - Publish the environment for expanded use and register intellectual property rights.
        - Conduct the research experiment with the target group.
4. **The training process consists of the following stages:**
    - Introduction to agents: teachers are introduced to a set of intelligent agents, each designed to perform specific tasks related to 3D graphics. These agents serve as mentors, guiding the teachers through various learning objectives.
    - Interactive learning modules: teachers engage in interactive modules, where the agents demonstrate key concepts in 3D graphics production and design thinking. The agents also facilitate hands-on exercises, enabling teachers to apply the concepts they have learned.
    - Collaborative problem-solving: the agents assist teachers in solving complex design challenges by breaking down problems into manageable tasks. The agents encourage creative problem-solving by adapting to the teachers' performance and providing tailored support.

4 Methodology

4.1 Research design

This study employed a quasi-experimental research design to investigate the effectiveness of a multi-smart agent-based training environment on enhancing both 3D graphics production and design thinking skills among primary school computer teachers. The study followed a mixed-methods approach, integrating both qualitative and quantitative data to ensure a comprehensive evaluation of the intervention. This approach is recommended for educational technology research where both objective skill assessments and subjective feedback are critical (Creswell and Creswell, 2017; Fraenkel et al., 2019).

4.2 Selection of participants

The participants in this study were selected using a purposive sampling technique, ensuring that the teachers chosen aligned with the study's objectives. A total of 60 primary school computer teachers from the Riyadh Educational Administration in Kafr El-Sheikh Governorate were included in the study. Specific inclusion criteria guided the selection process:

- **Teaching experience**: participants had at least two years of experience in teaching computer education at the primary level.
- **Familiarity with technology**: participants were required to have basic knowledge of 3D graphics or related technology, as assessed by a pre-study questionnaire.
- **Willingness to participate**: all participants volunteered to be part of the study and provided informed consent (Association, 2017).

4.3 Types of data used

Both qualitative and quantitative data were used to ensure the study captured comprehensive insights into the effectiveness of the training intervention. The data types are described as follows:

- **Quantitative data**: this was collected through structured cognitive tests, observation checklists, and design thinking scales to measure specific outcomes related to the participants' knowledge, practical skills, and creative problem-solving abilities (Field, 2018).
- **Qualitative data**: feedback and reflections from the participants were collected during and after the intervention through semi-structured interviews and reflective journals, providing insights into their learning experiences and perceptions of the training environment (Braun and Clarke, 2006).

4.4 Instruments for data collection

To measure the effectiveness of the training environment, the following instruments were employed:

- **Achievement test**: a validated cognitive test consisting of 67 multiple-choice questions was developed to assess the teachers' knowledge of 3D graphics production (Creswell and Creswell, 2017).
- **Observation checklist**: the observation checklist was used to evaluate the psychomotor skills of the participants as they engaged in 3D graphics production tasks (Fraenkel et al., 2019).
- **Evaluative checklist for final product quality**: this checklist was used to evaluate the final 3D graphics produced by the participants (Braun and Clarke, 2006).
- **Design thinking scale**: the scale was designed to assess the creative problem-solving and design-thinking abilities of participants (Mootee, 2013).

4.5 Data collection process

The data collection process was conducted in three phases:

1. **Pre-test phase**: before the intervention, all participants were administered the cognitive achievement test and the observation checklist to establish a baseline for their knowledge and skills in 3D graphics production.
2. **Intervention phase**: the participants engaged in a 5-week training program that utilized intelligent agents within a virtual environment (Weber et al., 2017).
3. **Post-test phase**: after completing the training program, participants were re-assessed using the same instruments (achievement test, observation checklist, evaluative checklist, and design thinking scale) to measure any changes in their cognitive understanding, practical skills, and creative problem-solving abilities.

4.6 Data analysis techniques

Quantitative data analysis: the quantitative data from the pre- and post-tests were analyzed using the Statistical Package for the Social Sciences (SPSS) version 27. Descriptive statistics (mean, standard deviation) were calculated to summarize the data (Field, 2018). Paired t-tests were conducted to determine the significance of any differences between pre-test and post-test scores, with a significance level set at $p \leq 0.05$ (Field, 2018).

Qualitative data analysis: qualitative data collected through participant reflections and interviews were analyzed using thematic analysis (Braun and Clarke, 2006). Data were coded to identify recurring themes and patterns related to participants' experiences with the multi-smart agent-based training environment.

4.7 Ensuring credibility of findings

Several steps were taken to ensure the credibility of the research findings:

- **Instrument validation**: all instruments were validated by a panel of experts in educational technology to ensure their relevance and accuracy in assessing 3D graphics production and design thinking skills (Creswell and Creswell, 2017).
- **Reliability testing**: the achievement test, observation checklist, and design thinking scale were pilot-tested to ensure internal consistency, and the Cronbach's alpha value was calculated to ensure reliability ($\alpha = 0.87$ for the achievement test) (Field, 2018).
- **Triangulation**: data were collected from multiple sources (tests, checklists, interviews) and analyzed using both quantitative and qualitative methods. This triangulation of data ensured a comprehensive evaluation of the intervention's effectiveness (Braun and Clarke, 2006).

- **Ethical Considerations**: Ethical approval was obtained from the relevant institutional review board, and all participants provided informed consent. Confidentiality and participant anonymity were maintained throughout the research process (Association, 2017).

5 Experimental results

5.1 Research design

The study utilized a one-group quasi-experimental design with pre-and post-test measurements to assess the impact of the independent variable on the research outcomes. This design was chosen because it effectively addresses the research objectives by allowing for the observation of changes attributable to the intervention.

- Cognitive test construction
  A cognitive achievement test was developed to evaluate participants' knowledge of 3D graphics production skills. The test initially contained 67 multiple-choice items. Educational technology experts reviewed the test to ensure its validity and reliability. The final version retained all 67 items, with each item contributing to a maximum total score of 67 points.
- Psychomotor domain observation checklist
  An observation checklist was created to assess psychomotor skills in 3D graphics production. Experts validated the checklist, which was finalized to include six main stages, 28 primary skills, 12 sub-skills, and 189 performance indicators. The checklist was designed to comprehensively evaluate the practical application of skills, resulting in a total possible score of 567 points.
- Final product quality evaluative checklist
  The evaluative checklist for the final product quality was developed to measure various aspects of 3D graphics production outcomes. It included 5 main areas, 13 sub-standards, and 130 evaluation indicators. This checklist was validated by experts to ensure it accurately reflects the quality standards expected in the field, with a total score of 260 points.
- Design thinking scale
  The Design Thinking Scale was initially crafted to measure participants' design thinking capabilities across 5 main dimensions and 40 statements. After expert feedback, the scale was refined to maintain its 5 dimensions and 40 sub-phrases, ensuring a comprehensive assessment of creative and analytical thinking skills.
- Pre-administration of research instruments
  1. The cognitive test and observation checklist were administered before introducing the training environment to establish baseline performance data.
  2. Scores from these pre-tests were recorded for comparison with post-test results during statistical analysis.
- Implementation of the research experiment
  1. A preparatory session was held to brief the participating teachers on the training plan and objectives.
  2. The main experimental phase occurred from February 18, 2023, to March 21, 2023, during which the intervention was applied.
- Post-administration of research instruments
  1. After completing the intervention, post-tests were administered, including the cognitive test, observation checklist, final product quality evaluative checklist, and design thinking scale.
  2. These instruments measured the changes in knowledge, skills, and quality of work attributable to the intervention.

  Data analysis was conducted using SPSS version 27. It involved statistical methods such as mean, standard deviation, percentages, and t-tests to evaluate the effectiveness of the interventions and quantify changes between pre- and post-test results. The analysis aimed to determine the significance and impact of the training environment on the participants' performance.

5.2 Research results

The research results can be presented as follows:

5.2.1 Q1: What specific skills in 3D graphics production are necessary for computer teachers in the primary stage?

The first research question is: "What skills are needed to produce three-dimensional drawings for computer teachers in primary school?" The research procedures answer this question, and all the steps for preparing a 3D graphics production skills list are listed. In its final form, the list consists of 28 primary skills, 12 sub-skills, and 189 sub-performance indicators.

5.2.2 Q2: What are the criteria for designing a training environment based on the multi-smart agent model?

The second research question is: "What are the criteria for designing a training environment based on the multiple intelligent agent model to develop 3D graphics production skills among computer teachers in the primary stage?" The research procedures answered this question, and all the steps for preparing the list of standards were listed. In its final form, the list consisted of 4 main areas, 23 sub-criteria, and 274 sub-indicators.

5.2.3 Q3: How does the educational design used in this training environment facilitate learning?

The research procedures address the third sub-question regarding the educational design used in the training environment based on the multiple intelligent agent model, outlining the steps of educational design following Al-Desouki's (2014) model.

5.2.4 Q4: What is the effectiveness of the multi-smart agent training environment in developing cognitive skills related to 3D graphics among teachers?

The answer to the fourth sub-question, focusing on the effectiveness of the training environment in developing the cognitive aspect of 3D graphics production skills among computer teachers in the primary stage, will involve testing the validity of the first hypothesis. The hypothesis suggests a statistically significant difference at a substantial level of ≤ 0.05 between the mean scores of the first and second experimental groups in the post-application of the cognitive test in favor of the second experimental group. The cognitive test results for both groups will be statistically processed to validate this hypothesis. See Table 1 for detailed results.

Table 1 reveals statistically significant differences in the mean scores between teachers of the first and second experimental groups post-application of the cognitive test. The scores of the second experimental group were notably higher than those of the first experimental group, with an overall mean score of 64.77 for the second group and 56.87 for the first group. The calculated "t" value was 11.15, statistically significant at the 0.01 significance level, indicating differences in favor of the second experimental group. Consequently, the first alternative hypothesis was accepted.

5.2.5 Q5: How effective is the training environment in enhancing the psychomotor domain of 3D graphics skills?

To answer the fifth research question, which states: "What is the effectiveness of a training environment based on the multiple intelligent agent model in developing the performance aspect of 3D graphics production skills among computer teachers in the primary stage?" the validity of the second hypothesis of the research will be tested. The hypothesis stated: "There is a statistically significant difference at a significance level ≤ 0.05 between the average scores of the teachers of the first experimental group and the scores of the teachers of the second experimental group in the post-application of the observation card in favor of the second experimental group." To test the validity of this hypothesis, the results of the two post-applications of the card were statistically processed. Observation for the two experimental groups, as shown in Table 2.

The results in Table 2 indicate a statistically significant difference in the mean scores between teachers in the first and second experimental groups post-application of the performance aspect note card for three-dimensional graphics production skills. The average scores of teachers in the second experimental group were higher than those in the first experimental group in the post-application of the observation card. The overall average score for teachers in the first experimental group post-application of the observation card was 482.53, while the overall average score for teachers in the second experimental group was 514.97. The calculated "t" value was 41.51, indicating statistical significance at a significance level of 0.01. The differences favored teachers in the second experimental group, thereby supporting the acceptance of the second alternative hypothesis.

5.2.6 Q6: Does the multi-smart agent training environment improve the quality of the final product in 3D graphics production?

The third research hypothesis was examined in response to the sixth research question regarding the effectiveness of a training environment based on the multiple intelligent agent model in enhancing the quality of the final product of 3D graphics production skills among primary-stage computer teachers. This hypothesis posited a statistically significant difference (≤0.05) between the average scores of the first and second experimental groups in the post-application of the final product quality assessment card, favoring the second experimental group. The statistical analysis of the post-application results of the final product quality evaluation card for both experimental groups is outlined in Table 3.

It is evident from the data presented in Table 3 that there exists a statistically significant difference between the mean scores of teachers in the first and second experimental groups after the application of the final product quality assessment card. The average scores of teachers in the second experimental group were notably higher than those in the first experimental group in the post-application of the evaluation card. Specifically, the mean total score for teachers in the first experimental group after the card application was 218.43, while for the second experimental group, it was 251.13. The computed "t" value stood at 51.00, demonstrating statistical significance at the 0.01 significance level. The observed differences favor the teachers in the second experimental group. Consequently, the third alternative hypothesis was affirmed.

5.2.7 Q7: How does the training environment impact design thinking skills among computer teachers in the primary stage?

Focusing on the effectiveness of a training environment based on the multiple intelligent agent model in developing design thinking among computer teachers in the primary stage involved testing the validity of the third hypothesis. This hypothesis posited: "There is a statistically significant difference at a significance level of ≤ 0.05 between the average scores of the teachers of the first experimental group and the scores of the teachers of the second experimental group in the post-application of the design thinking scale in favor of the second experimental group." The results of the post-application of the design thinking scale for the two experimental groups were subjected to statistical analysis to assess the validity of this hypothesis.

The analysis of Table 4 reveals notable differences between the two experimental groups regarding the design thinking scale. The second experimental group exhibited an arithmetic mean value of 106.72 with a standard deviation of 4.36. In contrast, the first experimental group showed an arithmetic mean of 85.70 with a standard deviation of 3.76. The calculated "t" value of 68.31 was statistically significant at the 0.001 significance level. This signifies a significant difference favoring the second experimental group in the design thinking scale. Consequently, the fourth alternative hypothesis was accepted.

TABLE 1 Results of teachers of both groups in the post-test administration.

Test	First experimental group		Second experimental group		*t*-test		
	Mean	SD	Mean	SD	*t*-value	DF	Sig.
Total marks	56.87		64.77	2.08	11.15	58	0.001

TABLE 2 Results of the two experimental groups in the post-administration of the observation checklist.

Test	First experimental group		Second experimental group		*t*-test		
	Mean	SD	Mean	SD	*t*-value	DF	Sig.
Total marks	482.53	6.29	514.97	6.09	41.51	58	0.001

TABLE 3 Results of the two experimental groups in the post-application of the assessment card.

Test	First experimental group		Second experimental group		t-test		
	Mean	SD	Mean	SD	*t*-value	DF	Sig.
Total marks	218.43	4.18	251.13	4.22	51.00	58	0.001

TABLE 4 Comparison of test scores between the first and second experimental groups.

Test	First experimental group		Second experimental group		*t*-test		
	Mean	SD	Mean	SD	*t*-value	DF	Sig.
Marks	85.70	3.76	106.72	4.36	68.31	58	0.001

6 Discussion

This study demonstrates the Multi-Smart Agent-Based Training environment's significant effectiveness in enhancing cognitive and psychomotor skills among elementary school computer teachers, specifically within the context of 3D graphics production and design thinking. The experimental results revealed statistically significant improvements in the performance of teachers who participated in the smart-agent-driven training compared to those in the control group. These improvements can be attributed to the interactive nature of the training, where the intelligent agents provided step-by-step instructions, immediate feedback, and practical assistance in solving complex tasks.

The study's results suggest that the intelligent agents' adaptive nature was critical in fostering practical skills and creative problem-solving capabilities. The intelligent agents tailored the learning process according to each teacher's progress, allowing personalized learning experiences that effectively addressed individual needs. This led to a noticeable increase in proficiency in 3D graphics production, facilitated by interactive engagement with real-world tasks rather than rote memorization. This finding underscores the strength of Multi-Smart Agent-Based Training in delivering content that is both accessible and intellectually challenging, leading to a deeper understanding and more hands-on mastery of the subject matter.

In addition to the technical skills, including design thinking principles within the training environment encouraged teachers to approach challenges creatively and critically. By applying innovative solutions to problems encountered during 3D graphics production, the teachers enhanced their technical proficiency and ability to think creatively. This combination of technical and cognitive skill development aligns well with the demands of modern educational environments, where teachers are expected to integrate technology and creative problem-solving into their instructional methods.

The results of this study are in agreement with previous research, such as Crompton and Burke (2020), which highlighted the potential of intelligent agents in enhancing technical skills in educational settings. Similarly, Weber et al. (2017) emphasized the effectiveness of intelligent agents in improving engagement and practical learning outcomes in virtual environments. However, this study extends previous research findings by focusing specifically on the domain of 3D graphics production and design thinking, which have been less explored in existing literature.

The novelty of this research lies in its dual focus on enhancing technical proficiency in 3D graphics production and fostering design thinking among educators. While previous studies have demonstrated the ability of intelligent agents to improve cognitive outcomes, this study provides evidence that such environments can also enhance psychomotor skills and creative problem-solving abilities. This is particularly significant as combining these two skill sets is critical in preparing educators to meet the evolving needs of 21st-century education.

The significance of these findings is further underscored by their potential applications in teacher professional development programs. The results indicate that Multi-Smart Agent-Based Training can effectively train teachers in technical subjects, where hands-on skills and creative thinking are essential.

By integrating intelligent agents into professional development programs, educational institutions can provide a dynamic and engaging learning experience that prepares teachers for the challenges of modern education.

However, this study has limitations. The sample size was relatively small, comprising only 60 participants from a specific educational administration, which may limit the generalizability of the findings. Additionally, the five-week duration of the training program may not have been sufficient to capture the long-term retention of skills. Future research could explore the impact of intelligent agents on skill retention over a longer period and across different educational contexts.

In conclusion, this study contributes valuable insights into the use of intelligent agent-based environments in teacher training, particularly for enhancing both technical and creative skills. The results demonstrate that intelligent agents can significantly improve cognitive and psychomotor skills, making them valuable tools in professional development programs. The findings also suggest the potential for expanding the application of such environments in other areas of education, ultimately helping educators integrate technology and innovative problem-solving approaches into their teaching practices.

7 Conclusions

The multi-smart agent-based training environment presents a novel and effective methodology for enhancing 3D graphics production skills and fostering design thinking among elementary school computer teachers. By integrating intelligent agents, this model provides a dynamic and adaptive learning experience that promotes cognitive development and technical proficiency. The findings from this study offer strong evidence that AI-powered agents significantly improve teachers' cognitive and psychomotor skills, enabling them to apply complex concepts with greater accuracy and creativity in practical scenarios.

This training environment addresses a critical gap in modern teacher education, particularly in technical domains like 3D graphics production, where traditional approaches often fall short. The intelligent agents effectively deepen the learning process and enhance engagement by offering immediate feedback and simulating real-world problem-solving scenarios. Furthermore, including design thinking in the training equips teachers with advanced technical skills and encourages innovative approaches to teaching and problem-solving in their classrooms.

Future research should aim to expand the application of this training model to a broader range of educational contexts. The intelligent agents must be refined to incorporate more advanced feedback mechanisms and simulate increasingly complex tasks. Additionally, exploring integrating collaborative learning and social interaction components within the agent-driven environment could further enhance its effectiveness, promoting cooperative learning and peer engagement among participants.

The multi-smart agent-based training environment has laid a robust foundation for the future of teacher education in technical fields. By advancing the functionality of intelligent agents and expanding the application of this model to diverse educational contexts, this approach holds significant potential to elevate teacher competencies and improve academic outcomes in an increasingly digital and technologically driven educational landscape.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Riyadh Educational Administration in Kafr El-Sheikh Governorate. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

SS: Writing – original draft, Software, Resources, Methodology, Funding acquisition. MA: Writing – review & editing, Resources, Methodology, Investigation. RA: Writing – review & editing, Visualization, Formal analysis, Data curation.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This work was supported by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia, under Project Grant KFU241496.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Abah, A. I. M. (2021). The degree to which kindergarten teachers practice twenty-first-century skills with kindergarten children in light of the kingdom 2030 from their point of view. *J. Educ., Al-Azhar Univer.* 189, 297–334.

Abdul Rahman, H. T. (2019). The effectiveness of electronic training in developing electronic course design skills. *J. Read. Knowl. Egypt. Soc. Read. Knowl.* 208, 203–224.

Abu Al-Dahab, M. M. A. (2020). Designing a participatory electronic training environment based on the two types of free/directed inquiry and its impact on developing some big data management competencies among information specialists. *Sci. J. Librar. Docum. Inform. Fac. Arts, Cairo Univers.* 2, 9–72.

Ahmed, A. A. (2023). Intelligent agents in educational environments: A review of recent developments. *Int. J. Educ. Technol.* 39, 53–72.

Ahmed, A. K. (2019). The intelligent agent and personal data protection. *Al-Amanah Magaz.* 31, 77–135.

Al-Desouki, M. I. (2014). The effectiveness of a synthetic strategy for electronic interaction in developing web-based instructional design skills among educational technology students at the Faculty of Specific Education. *Fayoum Univ. J. Educ. Psychol. Sci.* 3, 299341.

Al-Mozan, A. A. (2015). A proposed vision for a distinct, participatory electronic training environment in light of the aspirations of the faculty members at princess noura bint abdul rahman university and the future directions of electronic training. *J. College Educ. Al-Azhar Univer.* 164:2.

Al-Qarni, F. M. (2018). The impact of a training program based on a flipped learning environment to develop some e-training skills among female educational supervisors in the kingdom of saudi arabia. *Int. J. Human. Soc. Sci.* 42, 9–25.

Assiri, A. (2017). An intelligent agent to detect learner's learning styles automatically through an e-learning system in saudi arabia. *J. Eng. Sci. Inform. Technol.* 4:4.

Association, A. P. (2017). *Publication manual of the American Psychological Association*. Washington, DC: American Psychological Association.

Bassiouni, A. H. (2005). *Artificial Intelligence and the Intelligent Agent*. Cairo: Dar Al-Kutub Al-Ilmiyyah for Publishing and Distribution.

Bates, T. (2021). *Teaching in a Digital Age: Guidelines for Designing Teaching and Learning*. Vancouver, BC: Tony Bates Associates Ltd.

Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Qual. Res. Psychol.* 3, 77–101. doi: 10.1191/1478088706qp063oa

Brazier, F., and Ogston, E. (2011). "Agentscope: multi-agent systems development in focus," in *The 10th International Conference on Autonomous Agents and Multiagent Systems-Volume 1* (Richland, SC: International Foundation for Autonomous Agents and Multiagent Systems (IFAAMAS)), 389–396.

Creswell, J. W., and Creswell, J. D. (2017). *Research design: Qualitative, Quantitative, and Mixed Methods Approaches*. Washington DC: Sage Publications.

Crompton, H., and Burke, D. (2020). Mobile learning and educational technology: a systematic review of emerging trends. *Br. J. Educ. Technol.* 51, 611–623.

Ertmer, P. A., and Ottenbreit-Leftwich, A. (2023). Effective professional development for technology integration: lessons from teachers. *Contemp. Educ. Psychol.* 74:102200.

Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics*. Washington DC: Sage Publications Limited.

Fraenkel, J. R., Wallen, N. E., and Hyun, H. H. (2019). *How to Design and Evaluate Research in Education*. New York, NY: McGraw-Hill Education.

Gikandi, J. W., Morrow, D., and Davis, N. E. (2019). Online formative assessment in higher education: a review of the literature. *Comp. Educ.* 53, 104–125. doi: 10.1016/j.compedu.2011.06.004

Gilbert, S., and Levine, M. (2021). The impact of technology-enhanced learning on teacher professional development. *Educ. Technol. Res. Dev.* 69, 391–414.

Glick, S., Porter, D., and Smith, C. (2012). Student visualization: using 3-D models in undergraduate construction management education. *Int. J. Constr. Educ. Res.* 8, 26–46. doi: 10.1080/15578771.2011.619247

Iyad, F. (2015). The process of creative thinking in design. *J. Human. Soc. Sci. Stud.* 2:42.

Khalil, S. S. M. (2018). The relationship between adaptive display style (clips/pages) and learning style (sequential/holistic) in a virtual learning environment and its impact on 3d object production skills and engagement for educational technology students. *J. Educ. Technol. Stud. Res.* 35, 279–392.

Khamis, M. A. (2015). *E-Learning Resources, Part One: Individuals and Media*. Cairo: Dar Al-Sahab for Publishing and Distribution.

Kim, K. J., and Bonk, C. J. (2021). The future of online teaching and learning in higher education: the survey says. *EDUCAUSE Rev.* 56, 10–25.

Kiourt, C., Pavlidis, G., Koutsoudis, A., and Kalles, D. (2017). "Multi-agents based virtual environments for cultural heritage," in *26th International Conference on Information, Communication and Automation Technologies (ICAT)* (Sarajevo, Bosnia and Herzegovina: IEEE).

Liu, Y., Wang, L., Wang, Y., Wang, X., and Zhang, L. (2017). Multi-agent based scheduling in cloud manufacturing with dynamic task arrivals. *Procedia CIRP.* 72, 5850–5901. doi: 10.1016/j.procir.2018.03.138

Mootee, I. (2011). *Teaching Note "Design Thinking for Creativity and Business Innovation Series*." New York, NY: Idea Couture Inc.

Mootee, I. (2013). *Design Thinking for Strategic Innovation: What They can't Teach You at Business or Design School*. Hoboken, NJ: John Wiley & Sons.

Nazir, A. A. A. (2017). "Defining standards for intelligent, cooperative, and competitive agents in e-learning environments," in *Proceedings of the Third International Conference of the Faculty of Education* (Egypt: Arab Educators Association), 499–543.

Njenga, S. T., Oboko, R., Omwenga, E., and Maina, E. (2017). Use of intelligent agents in collaborative mlearning: case of facilitating group learner interactions. *I.J. Mod. Educ. Comp. Sci.* 10, 18–28. doi: 10.5815/ijmecs.2017.10.03

Qteit, G. (2011). "Computerization of teaching," in *House of Culture, Amman, 1st edition* (Richland, SC: International Foundation for Autonomous Agents and Multiagent Systems (IFAAMAS)).

Qteit, G. (2015). *Modern Learning and Teaching Technologies*. Amman: Dar Al-Thaqafa for Publishing and Distribution.

Robert, A. S. (2015). "Challenges in moving adaptive training & education from state-of-art to state-of-practice, volume 6," in *AIED 2015 Workshop Proceedings* (Orlando: U.S. Army Research Laboratory).

Saleh, A. M., and Saadeh, Z. A. (2022). Teacher competencies in the digital age: enhancing literacy and technology integration. *J. Educ. Technol. Soc.* 25, 66–78.

Salem, M. A. A. (2018). The impact of different styles of infographics on developing the skills of designing three-dimensional digital learning objects among educational technology students. *J. Faculty Educ. Port Said Univer.* 24, 347–369.

Scott, G., Porter, D., and Smith, C. (2012). *Student Visualization: Using 3-D Models in Undergraduate Construction Management Education*. Available at: http://tilt.colostate.edu/courseDD/pdfs/pub_fy11_ASC__JFormat_Stud_Visual_8_25_11_for_publication.pdf (accessed September 1, 2024).

Weber, T., Racaniére, S., Reichert, D. P., Buesing, L., Guez, A., Rezende, D. J., et al. (2017). "Imagination-augmented agents for deep reinforcement learning," in *Advances in Neural Information Processing Systems* (Richland, SC: International Foundation for Autonomous Agents and Multiagent Systems (IFAAMAS)), 5690–5701.